

## COMPARATIVE STUDY OF BEHAVIOR OF MANUFACTURED SAND AS A 100% REPLACEMENT OF NATURAL SAND IN MORTARS AND CONCRETE

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### ABSTRACT

*Sand being the requisite natural resource in the construction sector, unscrupulous and ruthless excavation of river beds to satisfy the ever-increasing demand for sand has impelled severe natural disparity. The un-regulated sand mining has ensued in the erosion of the river banks resulting in augmented flooding and causing a severe menace to biodiversity. In India, due to the inadequate sand resources and the enforced ban on sand mining in some states, illicit sand mining has increased. Henceforth, this complex problem in the construction field needs to be addressed. With this as the research background, the present research focuses on replacing 100% river sand [R-sand] with manufactured sand [M-sand]. In the current study, the behavior of the mortar and concrete manufactured with M-sand is compared with the natural sand on the factors of fresh and mechanical [dry density, compressive, tensile, and flexural] properties.*

**Keywords:** R-sand, M-sand, mortar, concrete, fresh and mechanical properties.

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### INTRODUCTION

For centuries human have been progressing their lives by the support of rivers. Rivers are the most important life supporting system of nature. Humans have been exploiting the resources of river without taking care of river ecosystem functions and its vitality maintenance. From ancient times humans have been using sand and aggregate materials for the development of civilization. Huge and developing civilization like India needs huge infrastructure and housing. So therefore along-with Food, Health, Defense and few other Civil Engineering plays very crucial role in the development of the country. Housing and infrastructure needs construction and construction needs cement, water, coarse aggregates and sand or fine aggregates. Since 2000 years sand has been an important material for construction and other industries like tile, brick, glass, adhesives, ceramics, etc. Such multiple uses led to rapid consumption growth. United Nations Environment Programme (UNEP) stipulates that “Sand and gravel represent the highest volume of raw material used on earth after water [1]. It is also said that “Concrete is the most produced material after food” [2] and sand is an integral fraction of concrete.

### LITERATURE REVIEW

Concrete is the most produced material after food [2]. Around 70% fraction of concrete is of total aggregates and sand [fine aggregates] in concrete is around 30% of total dry material. [3,4]. The coarse aggregates are particles more than 4.75 mm size and lesser size particles are fine aggregates [5].

Increasing demand and use of natural sand to fulfill the constructional need is becoming a crucial ecological challenge. National Green Tribunal [6], of India in 2020 in their report pointed out the a threat to bio-diversity, destruction of riverine vegetation, destruction of natural habitats of organisms living on the riverbeds, affect fish breeding and migration, spell disaster for the conservation of bird species i.e. overall damage to ecosystem of rivers. National Green Tribunal also elucidate threat to safety of bridges, weakening of riverbeds, and increase in salinity of water river.

Sustainable Sand Mining Management Guidelines – 2016 of Ministry of Environment, Forest and Climate Change - Government of India identified that the Rising requirement of construction materials like sand plays very vital for the health, physical character of the river and the different important functions of the river.[7]. The rate of use of natural sand and gravels greatly exceeds their natural renewal rates” [1] so the damage to ecosystem is inevitable.

To avoid the ecological issues and for the sustainable development it is the need of time to replace the river sand by other type of replacement. Many materials like foundry sand, steel slag, copper slag, imperial smelting furnace slag, blast furnace slag, coal bottom ash, ferrochrome slag, palm oil clinker [8] and also manufactured sand [9-13] may be used in place of river sand.

M-sand is nothing but the finer particles of the stone used for making coarse aggregates. The stones used for the manufacturing of aggregates are mostly not a part of river aggregates. The mining and crushing of stones for making aggregates also contribute in the pollution but mostly not on river ecology. Considering the volume of construction and huge need of fine aggregates the sources other than M sand cannot be made volumetrically available.

Rougher texture, more angular shapes of particles of M-Sand provide better bonding with cement than R-Sand. Zero impurities and higher packing density of M-Sand contributes better durability and compressive strength of concrete than R-Sand. [10,11,12]

## METHODOLOGY

Zone III river sand and M-Sand is used for comparison of following properties. The locally available R-sand is mostly of zone III. Therefore for comparison of properties zone III sands are preferred. For better comparison average zone III of both sands are made and used. i.e. as per IS 383 the 600 micron particle passing range of zone III is 60-79. For this investigation both R and M sands having 70% 600 micron particles passing are used. Investigation is carried out for strength of mortars, properties of concrete in fresh and hardened state as per relevant Indian Standard codes. 1:3:0.42 mortar cubes of size 7.06 X 7.06 X 7.06 cm, M-25 grade concrete cubes of size 15 X 15 X 15 cm and tested for 7<sup>th</sup> and 28<sup>th</sup> day compressive strength. Splitting tensile strength is also carried out on M-25 concrete cubes. M-25 concrete beams of size 70 X 15 X 15 cm are casted and tested for flexural strength test. For comparison all these samples are casted by using both R-Sand and M-sand.

## MATERIALS USED

**Cement:** Cement is the material used for the purpose of adhering and fastening the aggregates to produce tough mass called concrete. Cement used is ordinary Portland cement of Grade 53 of Ultratech make.

**Aggregates:** Aggregates contributes almost 70% fraction of concrete. Fraction of fine aggregates i.e. R-sand or M-sand is around 30% of concrete mass. They play the main role in required and essential properties of concrete. Aggregates are mostly a locally available material.

**R- Sand:** Usually commercial sand is obtained locally in Chandrapur, State of Maharashtra, India is from river beds. Zone of most of the local sand samples are of zone III, golden color and mostly are silica. Normally the specific gravity of local R-sand varies between 2.55-2.60. Locally available River sand is used.

**M- Sand:** M-sand used is made available from local manufacturer. The source stone is basalt. The specific gravity varies from 2.72-2.81. Available M-sand is almost free from impurities.

**Coarse Aggregates:** The source of coarse aggregates used is stone crushers based on local basalt depositions. Specific gravity ranges from 2.72-2.81. To graded mass of coarse aggregates is used.

**Water:** water safe for drinking can be used for construction without any testing. [3]. Therefore locally available potable municipal tap water is used.

Mix proportion of M-25 concrete for cubes and beams is given in "Table 1".

**Table 1: Mix Proportioning of M-25 Concrete**

| Type of Sand | Mix Proportion           | Cement                              | FA           | CA  | w/c ratio | Adopted Slump | Density                      |
|--------------|--------------------------|-------------------------------------|--------------|---|-----------|---------------|------------------------------|
| R-Sand       | 1:1.51:3.02<br>By weight | 409.09 kg<br>Ultratech OPC 53<br>Gr | 620.90<br>kg | 1235.16 kg<br>60% 20-10mm,<br>40% 10-4.75mm | 0.44      | 25-50<br>mm   | 2445.16<br>kg/m <sup>3</sup> |
| M-Sand       |                          |                                     |              |   |           | 25-50<br>mm   | 2493.10<br>kg/m <sup>3</sup> |

## RESULTS AND DISCUSSIONS

Comparison of Sieve Analysis of R-sand and M-Sand: Sieve analysis of sand prepared as average of zone III i.e 70% particles passing through 600 micron sieve. Sample size of 2000 grams is used. Sieve analysis is carried out as per IS: 2386 Part-I [14].

Average of zone III is average of range of particle size of 600 microns i.e.  $[(60+80)/2] = 70$ . Sieve Analysis of R-sand and M-Sand is tabulated in "Table 2".

**Table 2: Sieve Analysis of R-Sand and M-Sand**

| IS Sieve size [ mm ] | Weight of aggregate retained [gms] |        | Percentage retained [gms] |        | Cumulative % Retained |        | Cumulative % passing |        | Zone III Passing limits |
|----------------------|------------------------------------|--------|---------------------------|--------|-----------------------|--------|----------------------|--------|-------------------------|
|                      | R-Sand                             | M-Sand | R-Sand                    | M-Sand | R-Sand                | M-Sand | R-Sand               | M-Sand |                         |
| 4.75                 | 88.45                              | 73.85  | 4.42                      | 3.69   | 4.42                  | 3.69   | 95.58                | 96.31  | 90-100                  |
| 2.36                 | 157.63                             | 143.08 | 7.88                      | 7.20   | 12.30                 | 10.89  | 87.70                | 89.10  | 85-100                  |
| 1.18                 | 168.15                             | 185.33 | 8.41                      | 9.27   | 20.71                 | 20.16  | 79.29                | 79.84  | 75-100                  |
| 600 micron           | 184.46                             | 206.19 | 9.22                      | 10.36  | 29.93                 | 30.52  | 70.07                | 69.48  | 60-79                   |
| 300 micron           | 793.67                             | 785.61 | 39.68                     | 39.33  | 69.62                 | 69.85  | 30.38                | 30.15  | 12-40                   |
| 150 micron           | 571.41                             | 567.72 | 28.57                     | 28.38  | 98.19                 | 98.24  | 1.81                 | 1.76   | 0-10                    |
| silt                 | 35.94                              | 30.59  |                           |        | Fineness Modulus      |        | 2.351                | 2.333  |                         |

Sieve analysis of sand used for sample are mostly having similar particle distribution and percentage passing through 600

micron sieve is around 70% i.e average of range 60-79%.

Physical properties of R- sand and M-sand: Silt content, water absorption and specific gravity are tested as per IS: 2386 (Part III)[15].

Higher silt content, water absorption and specific gravity of M-sand than R-sand are observed. Higher value of water absorption is due to textured surface of M-sand. M-sand is a product of basalt rock hence value of specific gravity is higher than that of R-sand. Physical properties of R-sand and M-sand are determined as shown in “Table 3”.

**Table 3: Physical Properties of River Sand and M-Sand**

| Type of Sand     | Silt Content in % | Water Absorption% | Specific Gravity |
|------------------|-------------------|-------------------|------------------|
| R-Sand: zone III | 1.91              | 0.99              | 2.55             |
| M-Sand: zone III | 2.28              | 1.03              | 2.72             |

Comparison of Compressive strength of R-sand and M-Sand Mortar cubes: Compared with R-sand mortar cubes, M-sand mortar cubes show higher compressive strength. The 7th day strength is 9.32% and 28th day strength is 7.78% higher than compressive strength of R-sand mortar cubes. Compressive strength of R-sand mortar and M-sand mortar tested is given in “Table 4”.

**Table 4: Results of Compressive Strength of R- Sand and M-Sand Mortar**

| Type of Sand     | Size of Sample        | Proportion of mortar mix | Average Compressive Strength of Mortar Cubes |                 |
|------------------|-----------------------|--------------------------|--|-----------------|
|                  |                       |                          | 7th day in MPa                               | 28th Day in MPa |
| R-Sand: zone III | 7.06 X 7.06 X 7.06 cm | 1:3:0.42                 | 15.66  | 20.96           |
| M-Sand: zone III |                       |                          | 17.12  | 22.59           |

Workability: As per IS: 1199 [16] slump and compaction factor test is carried out and results are compared in “Table 5”.

**Table 5: Workability of R-Sand and M-Sand Concrete**

| Type of Sand used For M-25 | Slump Test in mm | Compaction Factor |
|----------------------------|------------------|-------------------|
| R-Sand: zone III           | 16               | 0.853             |
| M-Sand: zone III           | 00               | 0.821             |

Zone III sand is used for making concrete. Slump test value of M-sand is almost zero whereas R-sand concrete gives 16 mm slump. Compaction factor test results indicate the same trends. M-sand concrete is found stiffer than R-sand concrete. In case of M-sand concrete, for required workability admixtures should be used.

Strength of concrete: M-25 grade concrete cubes by using both M-sand and R-sand are casted. As per IS: 516 [17] compressive strength test and flexural strength test are carried out on 7 and 28 days cured samples. Splitting tensile strength test is also carried out as per IS: 5816 [18] on 7 and 28 days cured samples. Results are displayed in “Table 6”.

**Table 6: Compressive, Split Tensile Flexural Strength of R-Sand and M-Sand Concrete**

| Type of Sand     | Density | Compressive strength |          | Split Tensile Strength | Flexural Strength |
|------------------|---------|----------------------|----------|------------------------|-------------------|
|                  |         | 7th day              | 28th Day | 28th Day               | 28th Day          |
| R-Sand: zone III | 2445.16 | 23.07                | 32.14    | 4.03                   | 4.39              |
| M-Sand: zone III | 2493.10 | 25.52                | 35.89    | 4.22                   | 4.71              |

The 7th day compressive strength is 10.62% and 28th day strength is 11.67% higher than compressive strength of R-sand mortar cubes. Whereas Split Tensile Strength is 4.71% and Flexural Strength is found 7.29% more than R-sand concrete. The results of these three strength test indicate that strength point of view M-sand concrete is better than R-sand concrete.

## CONCLUSIONS

Strength of M-sand concrete is better than that of R-sand. Workability of M-sand concrete is comparatively less but can be easily managed by using little amount of admixture. Density of M-sand concrete is also better than R-sand concrete. M-sand can be manufactured for any zone and particle size distribution. A well processed M-sand can be replaced partially or fully replacement to river sand. Replacement of sand by such type of material is the need of the time. It is the recent future solution in Indian concrete industry until other suitable alternative fine aggregate is developed. Use of alternative to sand like M-sand will definitely contribute in preservation and upgrading of water bodies and ecology.

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